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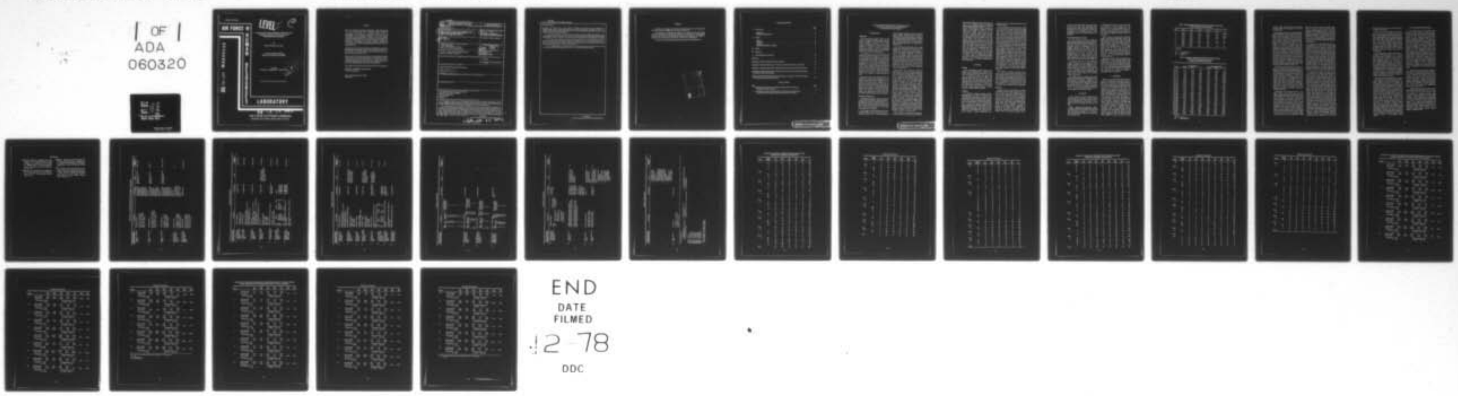

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EVALUATION OF THE AUTOMATED ADAPTIVE FLIGHT TRAINING SYSTEM'S AIR-TO-AIR INTERCEPT PERFORMANCE MEASUREMENT

By

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July 1978
Final Report for Period May 1976 – December 1977

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NOTICE

This final report was submitted by Flying Training Division, Air Force Human Resources Laboratory, Williams Air Force Base, Arizona 85224, under project 1123 with HQ Air Force Human Resources Laboratory, Brooks Air Force Base, Texas 78235.

This technical report has been reviewed and is approved for publication.

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The objectives of this study were: (a) to assess the effectiveness of the Automated Adaptive Flight Training System's (AAFTS) performance measurement package; and (b) to evaluate the efficiency of Operational Test and Evaluation (OT&E) procedures developed as a data-gathering tool for performance measurement.

and

In conjunction with TAC and USAFTAWC, AFHRL/FT carried out the requirements of the OT&E for the AAFTS device, in accordance with TAC Project 74A-119U, Annex A. A total of twelve crews, five student and seven operational, flew the F-4E WSTS #15/AAFTS simulator system located at Luke AFB, Arizona. Crews flew and were scored on nine different types of air-to-air intercepts that were programmed into the AAFTS device. The data revealed significant differences favoring the operational crews in two types of attacks (single turns and stern

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conversions). The AAFTS device, which utilized a 28-variable scoring format, was also examined on a variable-by-variable basis to observe performance differences between operational and student crews. Of the 28 variables measured, three were significantly different, two of which indicated superior performance by student crews. The data warranted the following conclusions:

(1.) As an instructional tool, the AAFTS has the potential to provide standardized objectively scored, training/evaluative scenarios for aircrews. The AAFTS functions as an autonomous programming device that directs aircrews through an air-to-air syllabus, a feature which could be the beginning point for automating aircrew training;

(2.) The performance measurement package performed adequately as an informational feedback tool, but requires more research to select and validate variables that discriminate better between aircrew skill levels. Failure to discriminate between skill levels could have occurred because the variables and their weights were based on the opinions of subject matter experts, not determined empirically; and

(3.) Use of OT&E procedures was minimally effective for performance measurement but served well as a means for acquiring aircrew subjective impressions on the system's overall training/evaluation potential.

PREFACE

This effort was conducted by the Flying Training Division of the Air Force Human Resources Laboratory, Williams Air Force Base, Arizona 85224.

The research was completed under project 1123, United States Air Force Flying Training Development; task 112303, the Exploitation of Simulation in Flying Training; and work unit 11230311, F-4E Model/Probe Visual System Application. Dr. William V Hagin was the project scientist and Mr. James F. Smith was the task scientist.

The report covers research performed between May 1976 and December 1977.

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I. INTRODUCTION

Background

The Automated Adaptive Flight Training System (AAFTS), developed by Logicon, Inc., and presently installed on the F-4E #15 Weapon System Training Set (WSTS) at Luke AFB, Arizona, was designed to provide an automated capability to train crews in ground controlled approaches (GCAs), tactical air navigation approaches (TACANs), air-to-air intercepts (AAI), and ground attack radar (GAR) missions.

An evaluation of the GCA portion of the AAFTS was conducted from May to November 1975 through the joint efforts of Tactical Air Command (TAC) and AFHRL/FT at the request of TAC/DOXS. Brown, Waag, & Eddowes (1975) concluded that: (a) there were no differences in performance on the training trials between the AAFTS groups and Standard groups; (b) the group trained by the machine controller performed as well as the group trained by human operators on the basis of criterion sorties; and (c) the AAFTS training did not appear to result in any adverse student GCA responses as measured during the study.

An operational test and evaluation (OT&E) was scheduled to evaluate other capabilities of the AAFTS which were delivered subsequent to the initial GCA evaluation. These included: (a) a re-evaluation of the GCA portion of the device; (b) AAI; (c) GAR; (d) Speech Understanding System (SUS); and (e) Remote Terminal Effectiveness. Results of the evaluation are available from USAF TAWC (TAC Project 74A 119U), Eglin AFB, Florida. The data gathered during the course of the OT&E provided the data source for this effort.

Performance Measurement

Data gathered during the OT&E were designed to answer specific objectives regarding device effectiveness for aircrew training. However, it was expected these data also would be sufficient for use as a base to evaluate the performance measurement schemata developed to score crew performances in the AAI mode.

In recent years, automated performance measurement (APM) of aircrew skill has become increasingly important, due to the emphasis placed upon simulation training and the advent of large capacity digital computing systems capable of handling performance measurement requirements. The digital computer has the capability to measure many variables simultaneously at a very rapid rate with extreme precision. Thus, APM can provide a large performance data base in a relatively short period of time.

One of the most difficult skill areas in which APM has been attempted is the air-to-air combat environment. Selection and implementation of variables that are fluid enough to be adapted to the ever-changing environment of air-to-air combat, yet sensitive enough to reliably discriminate among various levels of pilot proficiency, have been difficult to identify. Therefore, several strategies for measurement of air combat maneuvering (ACM) have been adopted by the research community. While most studies involved in this problem area use the ACM arena as a data source, many of the variables used in ACM are applicable to the AAI environment.

One strategy has attempted to classify the engagement into a series of individual maneuvers and to evaluate each of these maneuvers separately and then summate the findings into a composite score. A second strategy has attempted to select several variables that have intuitive logical appeal, integrate them into some composite scoring system, and analyze the results (TAC Project 74T-912F). A third strategy has been to select a relatively large number of potentially relevant variables for measurement, fly engagements, and then statistically eliminate those variables not contributing to the discriminability of pilot performance for a final reduced variable set. A fourth strategy has been to use the computer as an information system by measuring a set of preselected variables and reporting the results without any attempt to provide a composite score. A fifth strategy has been use of energy management as the key variable in measurement of ACM success (Deberg, 1977). Evaluation of each of these alternatives has produced less than adequate results. Typically, each APM system has strong and weak points so that no single system has been able to completely replace a careful, thorough, good subjective evaluation by an expert pilot.

A final strategy for performance measurement has been the use of criterion-referenced systems.

These systems usually have several preselected variables to be measured with error tolerances measured with bandwidths assigned to each variable and differing points awarded to aircrews as a function of their ability to maintain prescribed limits on the variables in question. In the AAI environment, variables often measure the geometry of the attack, missile launch parameters and other variables deemed important to an intercept (Shepherd, 1975). The AAFTS device used a scoring system of this nature. A set of 28 dependent variables was determined by the 4444 Operational Training Development Team (OTDT) and implemented into the computer by Logicon. These 28 variables included measures of: How closely the crew stayed to assigned airspeeds, altitudes and headings; how accurately the crew launched missiles; whether or not correct missile launching control procedures were followed/accomplished; and other variables specific to particular types of AAIs. All variables had acceptable bandwidths of performance that the crew had to maintain in order to accumulate scoring points in the scoring system.

II. METHOD

Subjects

Seven operationally qualified crews and five student crews participated in the OT&E of the AAFTS system. The seven operational crews came from the following locations: two crews from Luke AFB and one each from Eglin AFB, Holloman AFB, Seymour-Johnson AFB, Moody AFB, and Hill AFB. All operational crews had completed the F-4 student course and had been on operational duty an average of 12 months. The five student crews were members of the 550th Tactical Fighter Training Squadron (TFTS) enrolled in Course 4000B at Luke AFB.

Apparatus

The AAFTS is a parasitic computer based instructional device that has been interfaced with F-4E WSTS#15. The system is capable of automatically scoring and advancing aircrews through a 25-step GCA program (complete with computer-driven GCA instructions), a 12-step GAR program, and a 116-step AAI program (complete with computer-generated Ground Controlled Intercept (GCI) instructions and computer-driven speech understanding capabilities). The system has two cathode ray tubes (CRTs) with interactive keyboard consoles to observe performance concurrently or *post hoc*. Hard copy printouts of the tasks are available.

The AAI program is broken into nine modes, each with a various number of steps (AAI engagements) within it. The nine modes are: (a) single turn attacks (28 steps); (b) increasing/decreasing aspect attacks (12 steps); (c) stern conversion attacks (20 steps); (d) stern conversion ID passes (10 steps); (e) snap-ups (8 steps); (f) single turn attacks with stern conversion reattacks (6 steps); (g) no lock-on attacks (10 steps); (h) no GCI attacks (10 steps); and (i) tactical intercepts (12 steps). Within each mode, the steps were designed to present progressively more difficult intercepts as a function of the values of certain variables. These variables include range of contact of the hostile target, rate of closure of the target, target maneuverability, altitude separation, and lock-on range. While the AAFTS has a 28-variable standard format, only those variables relevant to the particular engagement underway are scored by the AAFTS APM system. Thus, within each mode of attack, the same variables are measured for all the steps. However, across modes, different variables are measured in order to best depict characteristic crew performance in the mode under consideration. Appendix A lists all performance variables, the scoring schemata, and when each variable is measured.

The AAFTS, in essence, becomes the instructor, since it assigns interceptor altitude, speed and heading and then vectors the interceptor to a target (usually flying straight and level at a particular altitude and heading). Upon completion of each AAI engagement, all APM variables are available for inspection via hard copy printout. The total cumulative score is displayed on the CRT immediately upon completion of the engagement.

Procedure

Training received in the AAFTS was severely constrained by TAC training requirements in the case of student crews and by OT&E limitations in the case of the operational crews. The operational crews were sent TDY to Luke AFB, one crew per week for seven weeks to fly the F4E WSTS#15/AAFTS for an average of two hours a day. All five student crews were enrolled in the F-4000B course during which they accomplished 25 simulator missions. Simulator missions 8 through 14 inclusive were devoted to AAI engagements as required by the 4000B course syllabus. During these seven missions, the instructors used the AAFTS device for training the student crews.

Computer advancement logic was not used, since the instructors chose which engagements they desired from the AAFTS repertoire of Mode/Step possibilities. Thus, the data gathered represents an accumulation of the available number of AAIs completed by each of the twelve crews used for the OT&E.

Experimental Design and Analysis

To study potential performance differences between operational crews and student crews, the data collection methods had to be considered carefully. The crews flew the simulator under different conditions, since the operational crews were adaptively scheduled by the AAFTS as often as possible, while the student crews flew what was dictated by instructors. Thus, while data were accumulated in each mode, the specific steps presented within each mode were flown under somewhat different conditions. Also, since the tasks measured by each mode were slightly different, each mode had to be evaluated separately.

T-statistics were used to test differences between the total scores (a summation of all the variables measured for each engagement completed) achieved by the student crews and operational crews for each mode. They were also used to test differences between operational and student crew performance on a variable-by-variable basis across modes, wherever the particular variable was measured.

The AAFTS device had specific point values assigned to performance error tolerance limits for each variable, as evidenced in Appendix A. An equal interval scoring technique was also employed to more accurately satisfy assumptions on which the statistic is based (i.e., a variable with scored values of 10, 8, 6, 3, 0 was arbitrarily rescaled to 4, 3, 2, 1, 0), and then between-groups differences were examined by mode and by variable.

III. RESULTS

Table 1 displays the mean, standard deviation, and t-statistic for each mode of attack summed across the operational and student crews, using the percent of possible total score variable (i.e., a composite score of all variables measured for each AAI).

Modes 1 (single-turn attacks) and 3 (stern-conversion attacks) produced significant performance differences between student and operational crews. The better performance, $p < .01$ and $p < .05$, respectively, was achieved by the operational group in both modes.

Descriptions of student crew and operational crew performance for each variable are in Appendices B and C. These appendices show the frequencies of scoring achieved by variable for student and operational crews, respectively, for all the dependent variables across all modes of intercepts.

Table 2 shows that performance differences between the operational and student crews on the eighth, (closure speed), 22nd (rollout aspect angle differential), and 23rd (stern rollout, overtake speeds) variables, using the AAFTS scoring configuration, were significant ($p < .05$). The operational crews performed better on the eighth variable, while the student crews showed the better performance on the 22nd and 23rd variables. When the equal interval scoring was computed, few changes were observed in significant findings on a variable-by-variable basis, as evidenced in Table 2.

The eighth, 22nd, and 23rd variables again were significant ($p < .05$), using the equal interval scoring system. The fifth variable (aim dot alignment error), which showed a performance difference of $p < .10$ using the AAFTS scoring, changed to $p < .05$, using equal interval scoring. Individual crew means used for comparisons of the AAFTS and equal-interval scoring are available in Appendices D and E, respectively.

IV. DISCUSSION

Modes 1 and 3 which showed better performance by the operational crews possibly can be explained as a function of their greater familiarity with air-to-air intercepts. The operational crews, by virtue of already having completed the student course, were more attuned to the air-to-air environment than were the student crews. The student crews usually flew several single-turn conversion intercepts (Mode 1), and if successful on those, in the judgment of the instructor, flew additional stern conversion intercepts (Mode 3), as time permitted, in accordance with syllabus requirements. These were the first intercepts flown by the students in a simulator environment. Conversely, while the operational crews flew single-turn conversions first in the simulator also, it was not their first exposure to intercepts. Thus, the operational crews flew comparatively superior intercepts in Mode 1. The operational crews also performed more successfully in Mode 3, as that particular mode of attack demanded extremely rapid computations from the weapon's system officer (WSO), in order to vector the aircraft

Table 1. **Means, Standard Deviation and t-Statistic by Mode Across Crews for the %-Possible Total Score Variable**

Mode	$\overline{X}$(Op)	σ(Op)	$\overline{X}$(Stud)	σ(Stud)	t-Value	p
1	89.9	13.3	73.2	29.4	3.22	.009**
2	79.8	22.7	84.4	12.0	−1.07	.31
3	81.3	16.4	72.3	21.7	2.41	.035*
4	55.7	23.6	67.4	10.5	−1.92	.08
5	67.6	33.6	Δ	Δ		
6	64.8	24.9	73.6	21.8	−1.82	.09
7	68.2	14.6	63.1	26.3	.69	.51
8	68.0	27.9	Δ	Δ		
9	63.2	32.6	52.4	34.8	1.10	.29

*$p < .05$.
**$p < .01$.

Op = Operational crews.
Stud = Student crews.
Δ = No data.

Table 2. **Comparison of Student and Operational Crew Performances, Using AAFTS and Equal-Interval Scoring by Variable Across Modes via t-Statistics**

	AAFTS Scoring			Equal Interval Scoring		
Variable	$\overline{X}$(Stud)	$\overline{X}$(Op)	t	$\overline{X}$(Stud)	$\overline{X}$(Op)	t
Var # 1	7.17	5.92	1.69	2.78	2.28	1.72
Var # 2	9.13	8.49	1.16	2.65	2.39	1.28
Var # 3	9.14	9.68	−2.00	2.73	2.91	−1.78
Var # 4	1.60	3.27	−0.85	0.21	0.45	−0.86
Var # 5	5.82	7.46	−2.02	2.23	2.90	−2.04*
Var # 6	8.10	8.59	−0.68	0.81	0.86	−0.68
Var # 7	13.88	15.29	−0.95	1.99	2.21	0.86
Var # 8	3.59	4.40	−2.55*	1.43	1.74	−2.50*
Var # 9	10.48	11.66	−1.39	2.10	2.33	1.38
Var #10	3.85	4.20	−1.16	0.77	0.84	−1.18
Var #11	32.30	34.74	−0.89	1.01	1.74	−0.97
Var #12	6.29	7.31	−0.98	0.63	0.73	−0.98
Var #13	11.70	8.57	1.74	1.64	1.17	1.79
Var #14	2.69	1.65	1.10	0.84	0.53	1.07
Var #15	7.60	8.39	−0.83	0.76	0.84	−0.83
Var #16	11.79	10.68	0.97	1.91	1.87	0.29
Var #17	8.64	8.32	0.55	0.86	0.83	0.56
Var#18	23.03	27.81	−1.33	1.15	1.39	−1.33
Var #19	5.29	3.81	1.06	0.53	0.38	1.05
Var #20	1.15	2.37	−1.48	0.98	2.37	−1.63
Var #21	4.50	1.64	2.01	1.50	0.82	1.17
Var #22	4.93	0.76	4.97*	2.47	0.38	4.97*
Var #23	6.56	1.60	3.96*	3.72	1.35	2.81*
Var #24	2.33	3.01	−0.36	0.23	0.30	−0.36
Var #25	8.95	8.65	0.65	0.90	0.87	0.66
Var #26	28.21	27.28	0.88	0.94	0.91	0.89
Var #27	32.54	32.80	−0.10	0.81	0.82	−0.10
Var #28	5.98	3.54	1.45	1.20	0.71	1.45

*$p < .05$.
Stud = Student crews.
Op = Operational crews.

correctly. Again, familiarity with the intercepts probably allowed the operational crews to score more effectively.

The remaining modes of attack showed little differences between operational crews and student crews. This finding can be attributed to two possibilities. First, according to the informal subjective reports of operational crews, they did not practice specific types of intercepts frequently. Rather, they were allowed the freedom of completing the intercept in the manner they determined to be most acceptable. Thus, their performance on the specific attacks desired by the AAFTS was not that much superior to the student crews, who, although they were experiencing the intercepts for the first time, learned rapidly and then achieved comparable scores. Secondly, the measurement scheme employed by the AAFTS device may not have measured certain subtle but important differences between the two sets of crews that could have changed the performance ratings achieved by the crews, or the scoring may not have properly weighted variables that would have shown differences between the crews.

Examination of performance by both sets of crews on a variable-by-variable basis revealed some differences in performance. The fifth variable, aim dot alignment error, showed superior performance by the operational crews under both systems of scoring. The exact probabilities, $p < .068$ for the AAFTS scoring and $p < .049$ using equal interval scoring, were similar. As evidenced, the operational crews placed the target display more precisely in the center of the allowable steering error (ASE) circle, which was critical in achieving a missile kill. As accuracy in placement of the target display on the center of the radar scope of the interceptor increased, the probability of achieving the kill also increased.

Operational crews performed better on the eighth variable, closure speed error, than did student crews with virtually no difference between the probability levels of the tests, as a function of type of scoring, $p < .027$ and $p < .030$, AAFTS scoring and equal interval scoring, respectively. In many intercepts the student crews were not attuned to the voice generation unit of the AAFTS and missed some of the vectoring instructions. Alternately, the student crews also listened too intently to the breakaway heading assignment, which was the last instruction given in a long series where one of the first instructions was the assigned vectoring instructions. This sequencing caused some indecision on what the appropriate heading should have been on the part of student crews. These two problems often forced the student crews to increase speed in order to reduce the probability of an extended tail chase to complete the intercept, which resulted in lower scores as the assigned parameters for closure speed were violated. More thorough inbriefing of the student crews on the voice qualities and sequencing of the computer-driven instructions might have alleviated their problems.

The student crews performed better than the operational crews on the rollout aspect angle variable (#22) and the stern rollout overtake speed variable (#23). The difference between the AAFTS and equal interval scoring was nonexistent for the rollout aspect angle variable, but rather noticeable on the rollout overtake speed variable with $p < .022$ and $p < .004$ for the AAFTS and equal interval scoring, respectively. This change in the probability levels of the statistical tests may be due to the fact that AAFTS scoring awarded increasingly higher point values for being within the specified tolerances as the target aircraft was approached. Thus, the AAFTS scoring was positively accelerated as the target aircraft was approached, whereas the equal interval scoring was linearly accelerated as the target was approached.

The rationale for student superiority on these two variables was as follows. As previously mentioned, student crews often "got behind" on stern-conversion intercepts (which was the only attack element on which variables 22 and 23 were measured; see Appendix A). The student crews frequently did end up in tail chases which put them directly behind the target aircraft and kept them well within the tolerances desired by the rollout, aspect angle variable. Improved performance by the student crews on the rollout overtake speed variable occurred in a similar manner. Once behind the target aircraft in a tail chase, the student crews had more time to more accurately monitor their overtake rates and, accordingly, adjusted to the desired rates of closure. Since the AAFTS had no scoring for time-to-kill or the overall geometry of the attack, any initial errors made by student crews were offset by the increased time expended in a tail chase, during which all remaining variables to be scored were performed well by the student crews. However, it must be remembered that operational crews usually performed more geometrically appropriate and more rapid kills. Their overall performance was usually superior to student crew performance which was probably a function of their superior ability to conceptualize the requirements of the entire

intercept rather than reacting to specific problems throughout the intercept.

In fact, there were relatively few differences shown as a function of scoring. This was due in part to the large percentage of dichotomous (two-level) variables present in the 28-variable format used by the AAFTS. As the equal-interval scoring was a strict linear transformation of the scored points, the t-values associated with all dichotomous variables were identical (within rounding error to the AAFTS scoring t-values). Of the remaining multiple-level variables, differences were also slight, since the change from the AAFTS scoring to equal-interval scoring was simply not that dramatic.

The AAFTS system performed adequately as a computer information system. On a variable-by-variable basis, the AAFTS was able to provide useful information regarding those parameters being measured; however, the combination of those individual variable scores into a total score that could discriminate between varying levels of crew sophistication was inadequate. In order to evaluate the 28-variable format empirically so that meaningful coefficient weights could be assigned to the variables, each crew should have completed a selected number of mode/step combinations many times to provide a good data base. Sufficient time to complete that requirement was simply not available in the OT&E environment.

By virtue of the points assigned to the variables, a crude attempt at coefficient weighting was already available within the AAFTS system. This system, however, decreased the probability of observing distinctions between crew skill levels due to its specific coefficient weighting. For example, variables 26 and 27 accounted for a composite of 70 points. Virtually all the crews achieved a kill (40 points–variable 27), and, similarly, few of the pilots crashed their simulated aircraft during the course of an intercept (30 points–variable 26) Further, most pilots correctly configured their switches a very high percentage of the time (80 points–variables 11, 18). Thus, a score of 150 points with little variance between the crews was achieved. The remaining, measured variables usually had no more than a maximum of ten points per variable, again with relatively small variances of performance across both operational and student crews. The net result was a lack of discrimination between the student and operational crews (i.e., good performance measurement) due to preselection of variable weights and little empirical validation of those assigned variable weights.

V. CONCLUSIONS/RECOMMENDATIONS

1. The scoring system of the AAFTS device faithfully provided excellent information about intercepts via hard copy records and CRT replays of the AAIs. This feature alone was obviously superior to crew or instructor memory, particularly in debriefing situations. This system of scoring should be considered to be a first attempt with an equivalent level of sophistication. The information provided was useful, but the integration of the variables, complete with appropriate empirical weighting, into a single, total score variable that would discriminate between skill levels of a crew is inadequate. Future efforts would require more extensive testing. Use of two-level variables and discrete multiple-level variables provides relatively small variances, as opposed to variables that are allowed to change on a continuous scale. A system with more discriminative power would probably be forced to utilize several continuous variables, in order to provide more detailed information on crew performance. Additionally, variables that measure time-to-kill and the overall geometry of the attack should be added.

2. The OT&E test environment provided a quick look into specific strengths and weakness of the AAFTS as a training system. These data were usually subjective and gathered via student/instructor commentary to the experimenter. Use of OT&E procedures to conduct a thorough performance measurement evaluation was extremely difficult. By attempting to maintain training programs without modification, the data requirement for a thorough performance measurement evaluation was compromised.

3. The potential for this system to be used as a standardized evaluative/training tool for simulation is excellent. In the future, the system could be configured to completely automate either training or testing scenarios. Test and training conditions would be guaranteed to be identical as a function of the computer and could be modified as necessary. With some further analysis and change of the variables under consideration, the objective scoring could be improved sufficiently to provide satisfactory objective measures of crew performance. This scoring could be made to conform to desired learning outcomes of various syllabi for different aircraft.

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APPENDIX A. AAI PERFORMANCE MEASUREMENT VARIABLES

	Aircrew Performance Measurement Variable	Scoring Data	When Sampled	Notes	Applicable AAI Modes*
1.	Maintain GCI-assigned altitude	Average altitude error: $0 \leq e\ (ft) < 100$: 10 points $100 \leq e\ (ft) < 150$: 8 points $150 \leq e\ (ft) < 200$: 6 points $200 \leq e\ (ft) < 250$: 3 points $e\ (ft) \geq 250$: 0 points	Every 2.4 seconds, starting when the F-4 should have reached the GCI-assigned altitude and ending when the target first appears on the F-4 radarscope.	Includes ±50 ft altimeter instrument error.	All but 5 and 9
2.	Maintain GCI-assigned Mach	Average Mach error: $0 \leq e\ (mach) < 0.07$: 10 points $0.07 \leq e\ (mach) < 0.10$: 8 points $0.10 \leq e\ (mach) < 0.17$: 6 points $e\ (mach) \geq 0.17$: 0 points	Every 2.4 seconds, starting when the F-4 should have reached the GCI-assigned Mach and ending when the target first appears on the F-4 radarscope.	Includes ±0.02 Mach instrument error.	All but 5
3.	Maintain GCI-assigned heading	Average heading error: $0 \leq e\ (deg) < 6$: 10 points $6 \leq e\ (deg) < 7$: 8 points $7 \leq e\ (deg) < 8$: 6 points $e\ (deg) \geq 8$: 0 points	Every 2.4 seconds, starting when the F-4 should have reached the CGI-assigned heading and ending when the target first appears on the F-4 radarscope.	Includes ±2 degrees instrument heading error.	All but 5, 8, and 9
4.	Obtain specified attack aspect angle as per problem control directive	Average AA error: $0 \leq e\ (deg) < 5$: 20 points $5 \leq e\ (deg) < 8$: 15 points $8 \leq e\ (deg) < 10$: 10 points $e\ (deg) \geq 10$: 0 points	Mode 2: Every 2.4 seconds while range to target is between 20 miles and 1.6 R_a. Mode 5: At trigger squeeze.	–	4, 5
5.	Attain proper aim dot alignment for triggering first AIM-7E missile	ASE circle radius: $0 \leq e\ (\%) < 25$: 10 points $25 \leq e\ (\%) < 50$: 8 points $50 \leq e\ (\%) < 75$: 6 points $75 \leq e\ (\%) < 100$: 3 points $e\ (\%) \leq 100$: 0 points	At trigger squeeze.	–	All but 4 and 7

Appendix A (*Continued*)

Aircrew Performance Measurement Variable	Scoring Data	When Sampled	Notes	Applicable AAI Modes*
6. Provide adequate radar missile preparation time for first AIM-7E	AIM-7E preparation: $\geq$ 4.0 seconds: 10 points $<$ 4.0 seconds: 0 points	At trigger squeeze.	–	All but 4 and 7
7. Trigger first AIM-7E missile at optimum range	AIM-7E firing range: 0.69 R_a to 0.5 R_a: 20 points R_a to 0.7 R_a or 0.49 R_a to 0.3 R_a: 15 points 0.29 R_a to R_{min}: 10 points Over R_a or under R_{min}: 0 points	At trigger squeeze.	–	All but 4 and 7
8. Achieve specified closure speed prior to triggering first AIM-7E	Closure speed: Under – 100 knots TAS, or over + 100 knots TAS differential: 5 points –51 to –100 knots TAS or +51 to +100 knots TAS differential: 3 points –50 to +50 knots TAS differential: 0 points	At trigger squeeze.	–	All but 4 and 7
9. Maintain "G" loading within first AIM-7E launch limits	AIM-7E "G"s: "Excellent": 20 points "Good": 15 points "Fair": 10 points "Poor": 5 points "Bad": 0 points	At trigger squeeze.	Classified 'G' loading values will be associated with each scoring category at a later date.	All but 4 and 7
10. Maintain lock-on after first AIM-7E trigger	Maintain lock-on after first AIM-7E trigger: 7 seconds or more: 5 points Less than 7 seconds: 0 points	Seven seconds after trigger squeeze.	–	All but 4 and 7
11. Correctly configure armament switches appropriate to AIM-7E launch	<u>Crew</u> — <u>Switch</u> — <u>Position</u> — <u>Points</u> WSO — Radar mode — RDR or MAP — 10 WSO — Polar Switch — LIN or CIRI — 10 A/C — Radar missile power — CW ON — 10 A/C — Master arm — ARM — 10	Switch At trigger squeeze. At trigger squeeze. At trigger squeeze. At trigger squeeze.	–	All but 4 and 7
12. Maintain aim-dot alignment and launch range for second AIM-7E missile	Aim dot within ASE circle *and* range within R_a, R_{min}: 10 points Aim dot outside ASE circle *or* range not within R_a, R_{min}: 0 points	At trigger squeeze for second AIM-7E.	–	All but 4 and 7

Appendix A (*Continued*)

	Aircrew Performance Measurement Variable	Scoring Data	When Sampled	Notes	Applicable AAI Modes*
13.	Trigger first AIM-Heat missile at optimum range	AIM-Heat firing range: 0.69 R_a to 0.5 R_a: 20 points R_a to 0.7 R_a or 0.49 R_a to 0.3 R_a: 15 points 0.29 R_a to R_{min}: 10 points Over R_a or under R_{min}: 0 points	At trigger squeeze.	–	3, 6, 7, 8, 9
14.	Maintain minimal heading differential at first AIM-Heat trigger	Heading differential at AIM-Heat trigger: "Excellent": 10 points "Good": 6 points "Fair": 3 points "Bad": 0 points	At trigger squeeze.	Classified heading differential values will be associated with each scoring category at a later date.	3, 6, 7, 8, 9
15.	Maintain first AIM-Heat look angle requirements	AIM-Heat look angle: +25 degrees: 10 points Greater than +25 degrees: 0 points	At trigger squeeze.	–	3, 6, 7, 8, 9
16.	Maintain "G" loading within first AIM-Heat launch limits	AIM-Heat 'G' loading: "Excellent": 20 points "Good": 10 points "Fair": 5 points "Bad": 0 points	At trigger squeeze.	Classified 'G' loading values will be associated with each scoring category at a later date.	3, 6, 7, 8, 9
17.	Maintain an aft position relative to the target	Maintain aft position: Remaining aft of the target's lateral axis: 10 points Flying ahead of target's lateral axis: 0 points	Constant check when within 6000' of target	This variable will be scored regardless of the type of missile fired.	3, 4, 6, 7, 8, 9
18.	Correctly configure armament switches appropriate to AIM-Heat launch	Crew / Switch / Position / Points A/C / Sight mode / A/A / 20 A/C / Master arm / ARM / 20	 At trigger squeeze. At trigger squeeze.	–	3, 6, 7, 8, 9
19.	Maintain look angle and launch range for second AIM-Heat missile	Look angle within +25° *and* range within R_a, R_{min}: 10 points Look angle outside +25° *or* range not within R_a R_{min}: 0 points	At trigger squeeze for second AIM-Heat.	–	3, 6, 7, 8, 9
20.	Maintain throttle advantage during stern conversion ID pass	Maintain throttle advantage during ID pass:	At specified ranges.	–	4

Appendix A (*Continued*)

Aircrew Performance Measurement Variable	Scoring Data	When Sampled	Notes	Applicable AAI Modes*
	(continued, see table below)			
21. Maintain roll-out altitude differential during stern conversion ID pass	Roll-out altitude differential:	At specified ranges.	–	4
22. Maintain roll-out aspect angle differential during stern conversion ID pass	Roll-out aspect angle:	At specified ranges.	–	4
23. Achieve correct stern roll-out overtake speeds during stern conversion attacks	Roll-out overtake speeds:	At specified closure ranges.	–	3

Range (nm)	V_c (knots)	Optimum Zone (knots)	Points Accumulated for Staying Within Optimum Zone
7	700	±100	1
6	600	±75	1
5	500	±50	1
4	350	±50	1
3	250	±50	2
2	100	+20 −15	2
1	50	+10 −7.5	4
1/2	20	+5 −5	4
1/4	20	±10	6

21. Roll-out altitude differential:

Range (nm)	Altitude from Target (feet)	Optimum Zone (feet)	Points Accumulated for Staying Within Optimum Zone
2	−250	±250	2
1	−250	±250	2
1/2	−250	±250	2
1/4	−250	±250	4

22. Roll-out aspect angle:

Range (nm)	Aspect Angle (degrees)	Optimum Zone (degrees)	Points Accumulated for Staying Within Optimum Zone
2	0	±2	2
1	0	±2	2
1/2	5	±3	2
1/4	10	±4	4

23. Roll-out overtake speeds:

Range (nm)	V_c (knots)	Optimum Zone (knots)	Points Accumulated for Staying Within Optimum Zone
7	700	±100	1
6	600	±100	1
5	500	±75	2
4	350	±75	2
3	250	±50	4
2	100	±25	5
1	100	±25	5

Appendix A (*Continued*)

	Aircrew Performance Measurement Variable	Scoring Data	When Sampled	Notes	Applicable AAI Modes*
24.	Achieve correct altitude differential at roll-out during tactical intercept	Altitude differential: Range (nm) / Optimum Zone (feet) / Points Accumulated for Staying Within Optimum Zone 1 / 1000 feet above to 4000 feet below target / 10 / Over 1000 feet above or more than 4000 feet below target / 0	At l-nm range astern of target.	–	9
25.	Maintain target on radarscope	Causing the target to first appear on radarscope within 60 seconds (90 seconds for mode 8) and not losing the target for more than 60 seconds: 10 points. Failure to acuquire target within 60 seconds (90 seconds for mode 8) of target briefing report or losing target for more than 60 seconds: 0 points	Continuous from target briefing report to first missile trigger squeeze. In mode 6, continuous to first AIM-Heat missile trigger squeeze. In mode 4, continuous until range to target equals 1/4 mile.	Run scored as MI if target not maintained on scope. Unless instructor intervenes, run to be terminated.	All
26.	Prevent 'crashing' aircraft	Prevent 'crashing' aircraft: Crash doesn't occur: 30 points Crash condition occurs: 0 points	Constant.	Run to be terminated and scored as MI if crash occurs. GP-4 logic to be utilized.	All
27.	Accomplish intercept mission	If MA does occur: 40 points If MA does not occur: 0 points	When intercept run is completed.	The aircrew will be credited with an MA unless one of the following situations occurs: a. The IP enters an MI at the keyboard. b. A crash occurs. c. A weapon is triggered in mode 4. d. A non-run specified weapon is triggered; e.g., the triggering of an AIM-Heat missile in mode 1.	All

Appendix A.(Continued)

Aircrew Performance Measurement Variable	Scoring Data	When Sampled	Notes	Applicable AAI Modes*
			e. An AIM-Heat is triggered before an AIM-7E is triggered in mode 6 f. The target is not acquired and maintained on the radarscope within the time constraints defined by PMV #25. g. The F-4 is not locked on to the target when the first AIM-7E is triggered. h. The target does not yet exist when the first AIM-Heat is triggered.	
28. Achieve collision course	Aim dot error: $0 \leq e\,(\text{deg}) < 11$: 10 points $11 \leq e\,(\text{deg}) < 16$: 5 points $e\,(\text{deg}) \geq 16$: 0 points	At first lock-on	–	1

*AAI mode definitions:

1. Single turn attack.
2. Increasing/decreasing aspect angle.
3. Stern conversion attack.
4. Stern conversion ID pass.
5. Snap-up attack.
6. Single-turn attack with stern conversion reattack.
7. Stern conversion attack with no lock-on.
8. 'No GCI' attack.
9. Tactical intercepts.

Maximum Scores:

Mode 1 – 240 points
Mode 2 – 250 points
Mode 3 – 370 points**
Mode 4 – 162 points
Mode 5 – 220 points
Mode 6 – 350 points
Mode 7 – 230 points
Mode 8 – 340 points**
Mode 9 – 340 points**

**Less 110 points if only AIM-7E triggered
Less 120 points if only AIM-Heat triggered

APPENDIX B. FREQUENCY DISTRIBUTION OF STUDENT CREW SCORING BY VARIABLE ACROSS MODES

Variable	Possible Scores	1st Crew	2nd Crew	3rd Crew	4th Crew	5th Crew	Total
1	10	9	41	22	17	20	109
	8	5	12	14	14	7	52
	6	4	1	4	7	6	22
	3	2	0	0	1	1	4
	0	11	9	11	4	3	38
Total		31	63	51	43	37	225
2	10	20	61	52	34	39	206
	8	5	1	1	7	2	16
	6	3	4	0	5	2	14
	0	5	2	1	2	0	10
Total		33	68	54	48	43	246
3	10	26	58	50	35	34	203
	8	0	0	0	1	0	1
	6	0	1	0	1	0	2
	0	5	4	1	6	1	17
Total		31	63	51	43	35	223
4	20	0	3	0	0	0	3
	15	0	1	1	0	0	2
	10	0	2	1	0	0	3
	0	5	10	10	0	11	36
Total		5	16	12	0	11	44
5	10	6	13	19	4	8	50
	8	12	10	12	6	10	50
	6	5	5	5	4	7	26
	3	2	0	1	2	3	8
	0	10	10	10	16	9	55
Total		35	38	47	32	37	189
6	10	25	29	39	21	28	142
	0	0	7	8	11	9	35
Total		25	36	47	32	37	177
7	20	13	20	24	3	17	77
	15	12	3	12	17	12	56
	10	0	0	3	0	1	4
	0	3	7	8	12	7	37
Total		28	30	47	32	37	174
8	5	17	28	34	20	30	129
	3	3	0	2	0	0	5
	0	8	10	11	12	7	48
Total		28	38	47	32	37	182
9	20	1	1	3	1	2	8
	15	14	18	23	13	22	90
	10	10	8	13	6	5	42
	5	0	15	0	1	1	17
	0	3	10	8	11	7	39
Total		28	52	47	32	37	196

Appendix B (*Continued*)

Variable	Possible Scores	1st Crew	2nd Crew	3rd Crew	4th Crew	5th Crew	Total
10	5	25	27	38	20	30	140
	0	3	11	9	12	7	42
Total		28	38	47	32	37	182
11	40	24	28	38	21	30	141
	30	1	1	1	0	0	3
	0	0	9	8	11	7	35
Total		25	38	47	32	37	179
12	10	24	25	29	9	27	114
	0	4	13	18	23	10	68
Total		28	38	47	32	37	182
13	20	6	7	1	5	4	23
	15	2	15	3	7	8	35
	10	0	2	2	2	1	7
	0	1	5	8	9	3	26
Total		9	29	14	23	16	91
14	10	0	1	1	5	7	14
	6	1	7	0	3	4	15
	3	0	4	3	2	0	9
	0	8	17	9	13	5	52
Total		9	29	13	23	16	90
15	1	8	25	7	16	13	69
	0	1	4	6	7	3	21
Total		9	29	13	23	16	90
16	20	5	6	7	13	7	37
	10	3	16	1	2	5	27
	5	0	2	0	2	0	4
	0	1	5	6	6	4	22
Total		9	29	13	23	16	90
17	10	21	37	25	26	22	131
	0	1	11	2	7	3	24
Total		22	48	27	33	25	155
18	40	0	11	6	14	9	40
	20	8	13	1	3	3	28
	0	1	5	6	6	4	22
Total		9	29	13	23	16	90
19	10	8	14	0	12	12	46
	0	1	15	13	11	4	44
Total		9	29	13	23	16	90

Appendix B (*Continued*)

Variable	Possible Scores	1st Crew	2nd Crew	3rd Crew	4th Crew	5th Crew	Total
20	0	0	3	2	1	0	6
	1	1	3	0	2	0	6
	2	1	1	0	0	0	2
	3	0	2	0	0	0	2
	4	1	0	0	0	0	1
	5	0	1	0	0	0	1
Total		3	10	2	3	0	18
21	6	3	0	2	3	0	8
	0	0	4	0	0	0	4
Total		3	4	2	3	0	12
22	6	2	5	2	2	0	11
	4	0	2	0	1	0	3
	2	0	3	0	0	0	3
	0	1	0	0	0	0	1
Total		3	10	2	3	0	18
23	0	0	0	5	3	0	8
	1	0	0	1	2	0	3
	5	0	0	1	0	0	1
	6	0	0	0	1	0	1
	8	0	0	1	0	0	1
	9	0	0	1	0	1	2
	10	0	0	0	1	0	1
	11	0	0	1	0	0	1
	12	0	0	0	1	0	1
	15	0	0	0	2	0	2
	20	0	0	0	1	0	1
Total		0	0	10	11	1	22
24	10	1	3	0	0	1	5
	0	1	3	2	5	5	16
Total		2	6	2	5	6	21
25	10	28	62	50	40	40	220
	0	4	6	4	8	3	25
Total		32	68	54	48	43	245
26	30	33	69	49	44	37	232
	0	0	0	4	4	6	14
Total		33	69	53	48	43	246
27	40	31	55	43	35	34	198
	0	2	14	10	13	9	48
Total		33	69	53	48	43	246
28	10	4	3	5	6	4	22
	5	2	0	6	1	2	11
	0	0	2	5	8	2	17
Total		6	5	16	15	8	50

APPENDIX C. FREQUENCY DISTRIBUTION OF OPERATIONAL CREW SCORING BY VARIABLE ACROSS MODES

Variable	Possible Scores	1st Crew	2nd Crew	3rd Crew	4th Crew	5th Crew	6th Crew	7th Crew	Total
1	10	5	11	5	17	11	9	7	65
	8	6	2	7	7	3	4	4	33
	6	2	2	3	4	5	5	2	23
	3	1	3	2	1	0	3	1	11
	0	3	6	7	1	16	11	9	53
Total		17	24	24	30	35	32	23	185
2	10	5	26	20	18	27	26	23	145
	8	6	2	0	1	7	4	2	22
	6	2	2	2	9	8	8	0	31
	0	3	1	2	4	3	1	0	14
Total		16	31	24	32	45	39	25	212
3	10	17	26	23	27	27	29	20	169
	8	0	0	0	0	0	0	0	0
	6	0	0	0	0	1	0	0	1
	0	0	1	1	1	1	2	0	6
Total		17	27	24	28	29	31	20	176
4	20	0	0	0	0	3	2	0	5
	15	1	0	0	0	0	1	0	2
	10	0	0	1	0	1	0	0	2
	0	1	6	5	4	4	8	6	34
Total		2	6	6	4	8	11	6	43
5	10	5	19	7	18	10	6	16	81
	8	4	4	8	3	10	15	6	50
	6	2	0	5	1	1	4	0	13
	3	0	0	0	3	3	3	0	9
	0	2	2	0	1	10	12	3	30
Total		13	25	20	26	34	40	25	183
6	10	11	23	20	26	21	29	22	152
	0	2	2	0	1	10	11	3	29
Total		13	25	20	27	31	40	25	181
7	20	7	22	4	21	6	8	15	83
	15	4	1	16	5	16	21	6	69
	10	0	0	0	0	0	0	0	0
	0	2	2	0	1	9	11	4	29
Total		13	25	20	27	31	40	25	181
8	5	11	23	20	25	18	28	21	146
	3	0	0	0	0	1	0	1	2
	0	2	2	0	2	11	12	3	32
Total		13	25	20	27	30	40	25	180
9	20	0	0	1	0	1	0	2	4
	15	8	15	14	14	18	19	18	106
	10	3	7	5	10	3	6	2	36
	5	0	1	0	2	0	1	0	4
	0	2	2	0	1	9	10	3	27
Total		13	25	20	27	31	36	25	177

Appendix C (*Continued*)

Variable	Possible Scores	1st Crew	2nd Crew	3rd Crew	4th Crew	5th Crew	6th Crew	7th Crew	Total
10	5	11	21	19	26	21	29	22	149
	0	2	4	1	1	10	11	3	32
Total		13	25	20	27	31	40	25	181
11	40	11	23	20	26	22	29	22	153
	30	0	0	0	0	0	0	0	0
	0	2	2	0	1	9	11	2	27
Total		13	25	20	27	31	40	24	180
12	10	11	22	9	21	21	27	21	132
	0	2	3	11	7	10	13	4	50
Total		13	25	20	28	31	40	25	182
13	20	2	1	1	0	1	2	0	7
	15	1	1	1	5	13	3	4	28
	10	0	2	0	0	1	0	0	3
	0	2	3	4	5	5	8	2	29
Total		5	7	6	10	20	13	6	67
14	10	0	0	0	0	3	2	0	5
	6	2	1	0	0	2	2	1	8
	3	2	1	0	1	2	0	1	7
	0	1	5	6	9	13	10	4	48
Total		5	7	6	10	20	14	6	68
15	10	4	7	5	8	20	8	4	56
	0	0	0	1	2	0	6	2	11
Total		4	7	6	10	20	14	6	67
16	20	1	1	1	2	9	5	2	21
	10	2	6	4	3	10	5	2	32
	5	1	0	0	2	0	0	0	3
	0	1	0	1	2	0	4	2	10
Total		5	7	6	9	19	14	6	66
17	10	5	5	11	20	36	21	16	114
	0	0	2	4	4	5	8	1	24
Total		5	7	15	24	41	29	17	138
18	40	3	5	5	7	10	1	2	33
	20	1	2	0	1	10	9	2	25
	0	1	0	1	1	0	4	2	9
Total		5	7	6	9	20	14	6	67
19	10	3	3	3	2	5	6	2	24
	0	2	4	4	8	15	8	4	45
Total		5	7	7	10	20	14	6	69
20	6	0	0	0	1	0	0	0	1
	5	0	0	0	0	1	0	0	1
	4	0	0	1	0	2	0	1	4
	3	1	0	0	0	0	1	0	2
	2	0	1	2	0	0	0	0	3
	1	0	0	0	0	0	0	0	0

Appendix C (*Continued*)

Variable	Possible Scores	1st Crew	2nd Crew	3rd Crew	4th Crew	5th Crew	6th Crew	7th Crew	Total
	0	2	2	2	2	0	0	0	8
Total		3	3	5	3	3	1	1	19
21	8	0	0	1	0	0	0	0	1
	6	0	0	2	0	1	0	0	3
	4	1	0	1	1	1	0	0	4
	2	0	1	0	0	0	0	0	1
	0	2	2	1	2	1	1	1	10
Total		3	3	5	3	3	1	1	19
22	6	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	1	1
	2	0	0	0	2	0	0	0	2
	0	3	3	5	1	3	1	0	16
Total		3	3	5	3	3	1	1	19
23	8	0	0	0	0	1	0	0	1
	6	0	0	2	0	1	0	0	3
	5	0	0	0	0	1	1	0	2
	4	0	1	1	0	1	0	0	3
	2	0	0	3	8	0	3	0	14
	1	0	0	0	0	0	1	0	1
	0	0	1	0	2	6	2	0	11
Total		0	2	6	10	10	7	0	35
24	10	0	1	0	3	0	2	2	8
	0	0	1	2	8	0	4	0	15
Total		0	2	2	11	0	6	2	23
25	10	14	28	27	30	48	20	24	191
	0	6	5	0	4	3	4	4	26
Total		20	33	27	34	51	24	28	217
26	30	19	28	26	29	45	40	28	215
	0	1	5	1	5	6	6	0	24
Total		20	33	27	34	51	46	28	239
27	40	14	24	24	27	43	36	27	195
	0	6	8	3	7	8	9	1	42
Total		20	32	27	34	51	45	28	237
28	10	0	0	0	4	1	3	2	10
	5	0	0	0	0	1	2	0	3
	0	0	0	0	2	0	1	3	6
Total		0	0	0	6	2	6	5	19

APPENDIX D. STUDENT AND OPERATIONAL CREW PERFORMANCE BY VARIABLE ACROSS MODES COMPARED BY T-STATISTIC USING AAFTS SCORING

Variable		1st Crew	2nd Crew	3rd Crew	4th Crew	5th Crew	6th Crew	7th Crew
1	Stud Crew $\bar{X}$s	5.16	8.13	6.98	7.60	7.97		
	Op Crew $\bar{X}$s	6.65	6.13	5.42	8.43	4.69	5.03	5.09
	$\bar{X}$(Student) = 7.17			$\bar{X}$(Operational) = 5.92				
	t = 1.69			$p < .113$	df = 10			
2	Stud Crew $\bar{X}$s	7.82	9.44	9.78	8.88	9.72		
	Op Crew $\bar{X}$s	6.88	9.29	8.83	7.57	8.31	8.72	9.84
	$\bar{X}$ (Student) = 9.13			$\bar{X}$ (Operational) = 8.49				
	t = 1.16			$p < .273$	df = 10			
3	Stud Crew $\bar{X}$s	8.39	9.30	9.80	8.49	9.71		
	Op Crew $\bar{X}$s	10.00	9.63	9.58	9.64	9.52	9.36	10.00
	$\bar{X}$ (Student) = 9.14			$\bar{X}$ (Operational) = 9.68				
	t = –2.00			$p < .071$	df = 10			
4	Stud Crew $\bar{X}$s	0.00	5.94	2.08	0.00	0.00		
	Op Crew $\bar{X}$s	7.50	0.00	1.66	0.00	8.75	5.00	0.00
	$\bar{X}$ (Student) = 1.60			$\bar{X}$ (Operational) = 3.27				
	t = –0.85			$p < .580$	df = 10			
5	Stud Crew $\bar{X}$s	6.86	6.32	6.79	3.69	5.46		
	Op Crew $\bar{X}$s	7.23	8.88	8.20	8.42	5.74	5.33	8.32
	$\bar{X}$ (Student) = 5.82			$\bar{X}$ (Operational) = 7.46				
	t = –2.02			$p < .068$	df = 10			
6	Stud Crew $\bar{X}$s	10.00	8.06	8.30	6.56	7.57		
	Op Crew $\bar{X}$s	8.46	9.20	10.0	9.63	6.77	7.25	8.80
	$\bar{X}$ (Student) = 8.10			$\bar{X}$ (Operational) = 8.59				
	t = –.068			$p < .517$	df = 10			
7	Stud Crew $\bar{X}$s	15.71	14.83	14.68	9.84	14.32		
	Op Crew $\bar{X}$s	15.39	18.20	16.00	18.33	11.61	11.88	15.60
	$\bar{X}$ (Student) = 13.88			$\bar{X}$ (Operational) = 15.29				
	t = –0.95			$p < .632$	df = 10			
8	Stud Crew $\bar{X}$s	3.36	3.68	3.74	3.13	4.05		
	Op Crew $\bar{X}$s	4.23	4.60	5.00	4.85	3.10	4.67	4.32
	$\bar{X}$ (Student) = 3.59			$\bar{X}$ (Operational) = 4.40				
	*t = –2.55			$p < .027$	df = 10			
9	Stud Crew $\bar{X}$s	11.79	8.56	11.81	8.75	11.49		
	Op Crew $\bar{X}$s	11.54	12.00	13.00	11.85	10.32	9.72	13.20
	$\bar{X}$ (Student) = 10.48			$\bar{X}$ (Operational) = 11.66				
	t = –1.39			$p < .192$	df = 10			
10	Stud Crew $\bar{X}$s	4.46	3.55	4.04	3.13	4.05		
	Op Crew $\bar{X}$s	4.23	4.20	4.75	4.82	3.39	3.63	4.40
	$\bar{X}$ (Student) = 3.85			$\bar{X}$ (Operational) = 4.20				
	t = –1.16			$p < .270$	df = 10			

Appendix D (*Continued*)

Variable		1st Crew	2nd Crew	3rd Crew	4th Crew	5th Crew	6th Crew	7th Crew
11	Stud Crew $\bar{X}$s	39.60	30.26	32.98	26.25	32.43		
	Op Crew $\bar{X}$s	33.85	36.80	40.00	38.52	28.39	29.00	36.67
	$\bar{X}$ (Student) = 32.30			$\bar{X}$ (Operational) = 34.74				
	t = –0.89			p < .602	df = 10			
12	Stud Crew $\bar{X}$s	8.57	6.58	6.17	2.81	7.30		
	Op Crew $\bar{X}$s	8.46	8.80	4.50	7.50	6.77	6.75	8.40
	$\bar{X}$ (Student) = 6.29			$\bar{X}$ (Operational) = 7.31				
	t = –0.98			p < .648	df = 10			
13	Stud Crew $\bar{X}$s	16.67	13.28	6.07	9.35	13.13		
	Op Crew $\bar{X}$s	11.00	7.86	5.83	7.50	11.25	6.54	10.00
	$\bar{X}$ (Student) = 11.70			$\bar{X}$ (Operational) = 8.57				
	t = 1.74			p < .192	df = 10			
14	Stud Crew $\bar{X}$s	.66	2.21	1.46	3.22	5.88		
	Op Crew $\bar{X}$s	3.60	1.29	0.00	0.33	2.40	2.43	1.50
	$\bar{X}$ (Student) = 2.69			$\bar{X}$ (Operational) = 1.65				
	t = 1.10			p < .297	df = 10			
15	Stud Crew $\bar{X}$s	8.89	8.62	5.38	6.96	8.13		
	Op Crew $\bar{X}$s	10.00	10.00	8.33	8.00	10.00	5.71	6.67
	$\bar{X}$ (Student) = 7.60			$\bar{X}$ (Operational) = 8.39				
	t = –0.83			p < .569	df = 10			
16	Stud Crew $\bar{X}$s	14.44	10.00	10.00	12.61	11.88		
	Op Crew $\bar{X}$s	9.00	11.43	10.00	8.88	14.73	10.71	10.00
	$\bar{X}$ (Student) = 11.79			$\bar{X}$ (Operational) = 10.68				
	t = 0.97			p < .643	df = 10			
17	Stud Crew $\bar{X}$s	9.55	7.71	9.26	7.88	8.80		
	Op Crew $\bar{X}$s	10.00	7.14	7.33	8.33	8.78	7.29	9.41
	$\bar{X}$ (Student) = 8.64			$\bar{X}$ (Operational) = 8.32				
	t = 0.55			p < .599	df = 10			
18	Stud Crew $\bar{X}$s	17.78	24.14	20.00	26.96	26.25		
	Op Crew $\bar{X}$s	28.00	34.29	33.33	33.33	30.00	15.71	20.00
	$\bar{X}$ (Student) = 23.03			$\bar{X}$ (Operational) = 27.81				
	t = –1.33			p < .211	df = 10			
19	Stud Crew $\bar{X}$s	8.89	4.83	0.00	5.22	7.50		
	Op Crew $\bar{X}$s	6.00	4.24	4.29	2.00	2.50	4.29	3.33
	$\bar{X}$ (Student) = 5.29			$\bar{X}$ (Operational) = 3.81				
	t = 1.06			p < .314	df = 10			
20	Stud Crew $\bar{X}$s	2.33	1.60	0.00	0.66			
	Op Crew $\bar{X}$s	1.00	0.66	1.60	2.00	4.33	3.00	4.00
	$\bar{X}$ (Student) = 1.15			$\bar{X}$ (Operational) = 2.37				
	t = –1.48			p < .170	df = 9			

Appendix D (*Continued*)

Variable		1st Crew	2nd Crew	3rd Crew	4th Crew	5th Crew	6th Crew	7th Crew
21	Stud Crew $\overline{X}$s	6.00	0.00	6.00	6.00			
	Op Crew $\overline{X}$s	1.33	0.66	4.80	1.33	3.33	0.00	0.00
	$\overline{X}$ (Student) = 4.50			$\overline{X}$ (Operational) = 1.64				
	t = 2.01			$p < .192$	df = 9			
22	Stud Crew $\overline{X}$s	4.00	4.40	6.00	5.33			
	Op Crew $\overline{X}$s	0.00	0.00	1.33	0.00	0.00	0.00	4.00
	$\overline{X}$ (Student) = 4.93			$\overline{X}$ (Operational) = .76				
	*t = 4.97			$p < .001$	df = 9			
23	Stud Crew $\overline{X}$s			3.40	7.27	9.00		
	Op Crew $\overline{X}$s	0.00	2.00	3.60	1.60	2.30	1.71	0.00
	$\overline{X}$ (Student) = 6.56			$\overline{X}$ (Operational) = 1.60				
	*t = 3.96			$p < .004$	df = 8			
24	Stud Crew $\overline{X}$s	5.00	5.00	0.00	0.00	1.66		
	Op Crew $\overline{X}$s	0.00	5.00	0.00	2.73	0.00	3.33	10.00
	$\overline{X}$ (Student) = 2.33			$\overline{X}$ (Operational) = 3.01				
	t = –0.36			$p < .725$	df = 10			
25	Stud Crew $\overline{X}$s	8.75	9.12	9.26	8.33	9.30		
	Op Crew $\overline{X}$s	7.00	8.48	10.00	8.82	9.41	8.33	8.57
	$\overline{X}$ (Student) = 8.95			$\overline{X}$ (Operational) = 8.65				
	t = 0.65			$p < .536$	df = 10			
26	Stud Crew $\overline{X}$s	30.00	30.00	27.74	27.50	25.81		
	Op Crew $\overline{X}$s	28.50	25.45	28.89	25.59	26.47	26.09	30.00
	$\overline{X}$ (Student) = 28.21			$\overline{X}$ (Operational) = 27.28				
	t = 0.88			$p < .596$	df = 10			
27	Stud Crew $\overline{X}$s	37.58	31.88	32.45	29.17	31.63		
	Op Crew $\overline{X}$s	28.00	30.00	35.56	31.76	33.73	32.00	38.57
	$\overline{X}$ (Student) = 32.54			$\overline{X}$ (Operational) = 32.80				
	t = –0.10			$p < .901$	df = 10			
28	Stud Crew $\overline{X}$s	8.33	6.00	5.00	4.33	6.25		
	Op Crew $\overline{X}$s	0.00	0.00	0.00	6.67	7.50	6.67	4.00
	$\overline{X}$ (Student) = 5.98			$\overline{X}$ (Operational) = 3.54				
	t = 1.45			$p < .175$	df = 10			

Note. All t-statistic numerators were computed $\overline{X}$ (Student) – $\overline{X}$ (Operational).
*$p < .05$.
Stud = Student crews.
Op = Operational crews.

APPENDIX E. STUDENT AND OPERATIONAL CREW PERFORMANCE BY VARIABLE ACROSS MODES COMPARED BY T-STATISTICS USING EQUAL INTERVAL SCORING

Variable		1st Crew	2nd Crew	3rd Crew	4th Crew	5th Crew	6th Crew	7th Crew
1	Stud Crew $\overline{X}$s	1.97	3.21	2.71	2.91	3.08		
	Op Crew $\overline{X}$s	2.53	2.38	2.04	3.27	1.80	1.91	1.96
	$\overline{X}$ (Student) = 2.78			$\overline{X}$ (Operational) = 2.28				
	t = 1.72			p < .113	df = 10			
2	Stud Crew $\overline{X}$s	2.21	2.75	2.93	2.52	2.86		
	Op Crew $\overline{X}$s	1.81	2.71	2.58	2.03	2.29	2.41	2.92
	$\overline{X}$ (Student) = 2.65			$\overline{X}$ (Operational) = 2.39				
	t = 1.28			p < .228	df = 10			
3	Stud Crew $\overline{X}$s	2.52	2.78	2.94	2.51	2.91		
	Op Crew $\overline{X}$s	3.00	2.79	2.88	2.89	2.83	2.81	3.00
	$\overline{X}$ (Student) = 2.73			$\overline{X}$ (Operational) = 2.91				
	t = −1.78			p < .103	df = 10			
4	Stud Crew $\overline{X}$s	0.00	0.81	0.25	0.00	0.00		
	Op Crew $\overline{X}$s	1.00	0.00	0.17	0.00	1.25	0.73	0.00
	$\overline{X}$ (Student) = 0.21			$\overline{X}$ (Operational) = 0.45				
	t = −.866			p < .589	df = 10			
5	Stud Crew $\overline{X}$s	2.57	2.42	2.62	1.38	2.14		
	Op Crew $\overline{X}$s	2.77	3.52	3.10	3.44	2.21	2.00	3.28
	$\overline{X}$ (Student) = 2.33			$\overline{X}$ (Operational) = 2.90				
	*t = −2.04			p < .049	df = 10			
6	Stud Crew $\overline{X}$s	1.0	0.81	0.83	0.66	0.76		
	Op Crew $\overline{X}$s	0.85	0.92	1.0	0.96	0.68	0.73	0.88
	$\overline{X}$ (Student) = 0.81			$\overline{X}$ (Operational) = 0.86				
	t = −0.68			p < .517	df = 10			
7	Stud Crew $\overline{X}$s	2.25	2.20	2.11	1.34	2.05		
	Op Crew $\overline{X}$s	2.23	2.72	2.25	2.70	1.61	1.65	2.28
	$\overline{X}$ (Student) = 1.99			$\overline{X}$ (Operational) = 2.21				
	t = 0.86			p < .586	df = 10			
8	Stud Crew $\overline{X}$s	1.32	1.47	1.49	1.25	1.62		
	Op Crew $\overline{X}$s	1.69	1.84	2.00	1.85	1.23	1.87	1.72
	$\overline{X}$ (Student) = 1.43			$\overline{X}$ (Operational) = 1.74				
	*t = −2.50			p < .030	df = 10			
9	Stud Crew $\overline{X}$s	2.36	1.71	2.36	1.75	2.30		
	Op Crew $\overline{X}$s	2.31	2.40	2.60	2.37	2.06	1.94	2.64
	$\overline{X}$ (Student) = 2.10			$\overline{X}$ (Operational) = 2.33				
	t = 1.38			p < .196	df = 10			
10	Stud Crew $\overline{X}$s	0.89	0.71	0.81	0.63	0.81		
	Op Crew $\overline{X}$s	0.85	0.84	0.95	0.96	0.68	0.73	0.88
	$\overline{X}$ (Student) = 0.77			$\overline{X}$ (Operational) = 0.84				
	t = −1.18			p < .265	df = 10			

Appendix E (*Continued*)

Variable		1st Crew	2nd Crew	3rd Crew	4th Crew	5th Crew	6th Crew	7th Crew
11	Stud Crew $\overline{X}$s	1.96	1.50	1.64	1.31	1.62		
	Op Crew $\overline{X}$s	1.69	1.84	2.00	1.93	1.42	1.45	1.83
	$\overline{X}$ (Student) = 1.16			$\overline{X}$ (Operational) = 1.74				
	t = –0.97			p < .642	df = 10			
12	Stud Crew $\overline{X}$s	0.86	0.66	0.62	0.28	0.73		
	Op Crew $\overline{X}$s	0.85	0.88	0.45	0.75	0.84	0.68	0.68
	$\overline{X}$ (Student) = 0.63			$\overline{X}$ (Operational) = 0.73				
	t = –0.98			p < .648	df = 10			
13	Stud Crew $\overline{X}$s	2.44	1.83	0.79	1.35	1.81		
	Op Crew $\overline{X}$s	1.60	1.00	0.83	1.00	1.50	0.92	1.33
	$\overline{X}$ (Student) = 1.64			$\overline{X}$ (Operational) = 1.17				
	t = 1.79			p < .101	df = 10			
14	Stud Crew $\overline{X}$s	0.22	0.72	0.46	1.00	1.81		
	Op Crew $\overline{X}$s	1.20	0.43	0.00	0.10	0.75	0.71	0.50
	$\overline{X}$ (Student) = 0.84			$\overline{X}$ (Operational) = 0.53				
	t = 1.07			p < .301	df = 10			
15	Stud Crew $\overline{X}$s	0.89	0.86	0.54	0.70	0.81		
	Op Crew $\overline{X}$s	1.00	1.00	0.83	0.80	1.00	0.57	0.67
	$\overline{X}$ (Student) = 0.76			$\overline{X}$ (Operational) = 0.84				
	t = –0.83			p < .569	df = 10			
16	Stud Crew $\overline{X}$s	2.33	1.79	1.54	1.96	1.94		
	Op Crew $\overline{X}$s	1.60	2.14	1.83	1.56	2.47	1.79	1.67
	$\overline{X}$ (Student) = 1.91			$\overline{X}$ (Operational) = 1.87				
	t = 0.29			p < .77	df = 10			
17	Stud Crew $\overline{X}$s	0.95	0.77	0.93	0.79	0.88		
	Op Crew $\overline{X}$s	1.00	0.71	0.73	0.83	0.88	0.72	0.94
	$\overline{X}$ (Student) = 0.86			$\overline{X}$ (Operational) = 0.83				
	t = 0.56			p < .593	df = 10			
18	Stud Crew $\overline{X}$s	0.89	1.21	1.00	1.35	1.31		
	Op Crew $\overline{X}$s	1.40	1.71	1.67	1.67	1.50	0.79	1.00
	$\overline{X}$ (Student) = 1.15			$\overline{X}$ (Operational) = 1.39				
	t = –1.33			p < .211	df = 10			
19	Stud Crew $\overline{X}$s	0.89	0.48	0.00	0.52	0.75		
	Op Crew $\overline{X}$s	0.60	0.43	0.43	0.20	0.25	0.43	0.33
	$\overline{X}$ (Student) = 0.53			$\overline{X}$ (Operational) = 0.38				
	t = 1.05			p < .38	df = 10			
20	Stud Crew $\overline{X}$s	2.33	1.60	0.00	0.00	none		
	Op Crew $\overline{X}$s	1.00	0.60	1.60	2.00	4.32	3.00	4.00
	$\overline{X}$ (Student) = 0.98			$\overline{X}$ (Operational) = 2.37				
	t = –1.63			p < .135	df = 9			

Appendix E (*Continued*)

Variable		1st Crew	2nd Crew	3rd Crew	4th Crew	5th Crew	6th Crew	7th Crew
21	Stud Crew $\overline{X}$s	2.00	0.00	2.00	2.00	none		
	Op Crew $\overline{X}$s	0.66	0.33	2.40	0.66	1.66	0.00	0.00
	$\overline{X}$ (Student) = 1.50			$\overline{X}$ (Operational) = 0.82				
	$t = 1.17$			$p < .272$	$df = 9$			
22	Stud Crew $\overline{X}$s	2.00	2.20	3.00	2.66	none		
	Op Crew $\overline{X}$s	0.00	0.0	0.0	0.66	0.00	0.00	2.00
	$\overline{X}$ (Student) = 2.47			$\overline{X}$ (Operational) = 0.38				
	$^*t = 4.97$			$p < .001$	$df = 9$			
23	Stud Crew $\overline{X}$s	none	none	1.90	4.27	5.00		
	Op Crew $\overline{X}$s	0.00	1.50	3.00	1.60	1.80	1.57	0.00
	$\overline{X}$ (Student) = 3.72			$\overline{X}$ (Operational) = 1.35				
	$^*t = 2.81$			$p < .022$	$df = 8$			
24	Stud Crew $\overline{X}$s	0.50	0.50	0.00	0.00	0.17		
	Op Crew $\overline{X}$s	0.00	0.50	0.00	0.27	0.00	0.33	1.00
	$\overline{X}$ (Student) = 0.23			$\overline{X}$ (Operational) = 0.30				
	$t = -0.36$			$p < .725$	$df = 10$			
25	Stud Crew $\overline{X}$s	0.88	0.91	0.93	0.83	0.93		
	Op Crew $\overline{X}$s	0.70	0.85	1.00	0.88	0.94	0.83	0.86
	$\overline{X}$ (Student) = 0.90			$\overline{X}$ (Operational) = 0.87				
	$t = 0.66$			$p < .532$	$df = 10$			
26	Stud Crew $\overline{X}$s	1.00	1.00	0.92	0.92	0.86		
	Op Crew $\overline{X}$s	0.95	0.85	0.96	0.85	0.88	0.87	1.00
	$\overline{X}$ (Student) = 0.94			$\overline{X}$ (Operational) = 0.91				
	$t = 0.89$			$p < .602$	$df = 10$			
27	Stud Crew $\overline{X}$s	0.94	0.80	0.81	0.73	0.79		
	Op Crew $\overline{X}$s	0.70	0.75	0.89	0.79	0.84	0.80	0.96
	$\overline{X}$ (Student) = 0.81			$\overline{X}$ (Operational) = 0.82				
	$t = -0.10$			$p < .901$	$df = 10$			
28	Stud Crew $\overline{X}$s	1.67	1.20	1.00	0.87	1.25		
	Op Crew $\overline{X}$s	0.00	0.00	0.00	1.33	1.50	1.33	0.80
	$\overline{X}$ (Student) = 1.20			$\overline{X}$ (Operational) = 0.71				
	$t = 1.45$			$p < .175$	$df = 10$			

Note. All t-statistic numerators were computed $\overline{X}$ (Student) – $\overline{X}$ (Operational).
$^*p < .05$.

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